# Assessment of In-Vehicle Exposure to Traffic-Related Ultrafine Particles and Other Pollutants

**SCAQMD Conference on Ultrafine Particles**

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# Outline

- Why concerned about in-vehicle ultrafine particles (UFP)
- Why in-vehicle concentrations high
- Importance of high emitting vehicles
- Study performed
  - Route, instruments
  - Time series plots
  - Concentration predictors
  - Associations with annual traffic count data
- Exposure implications

# Importance of UFP

- Weak associations with PM mass
- On an equal mass basis may be more toxic
- Dose differences
  - Deposition efficiency
  - Penetration into blood stream, cell mitochondria, can cross blood/brain barrier
- In-vehicle UFP fresher—higher fraction of volatile particles (temp. dependent)

# In-Vehicle Concentrations

- **Air exchange rates in vehicles high**
- **Road Concentrations:**

  **Centerline > Roadside >> Ambient**

- **In-vehicle concentrations ~ centerline**

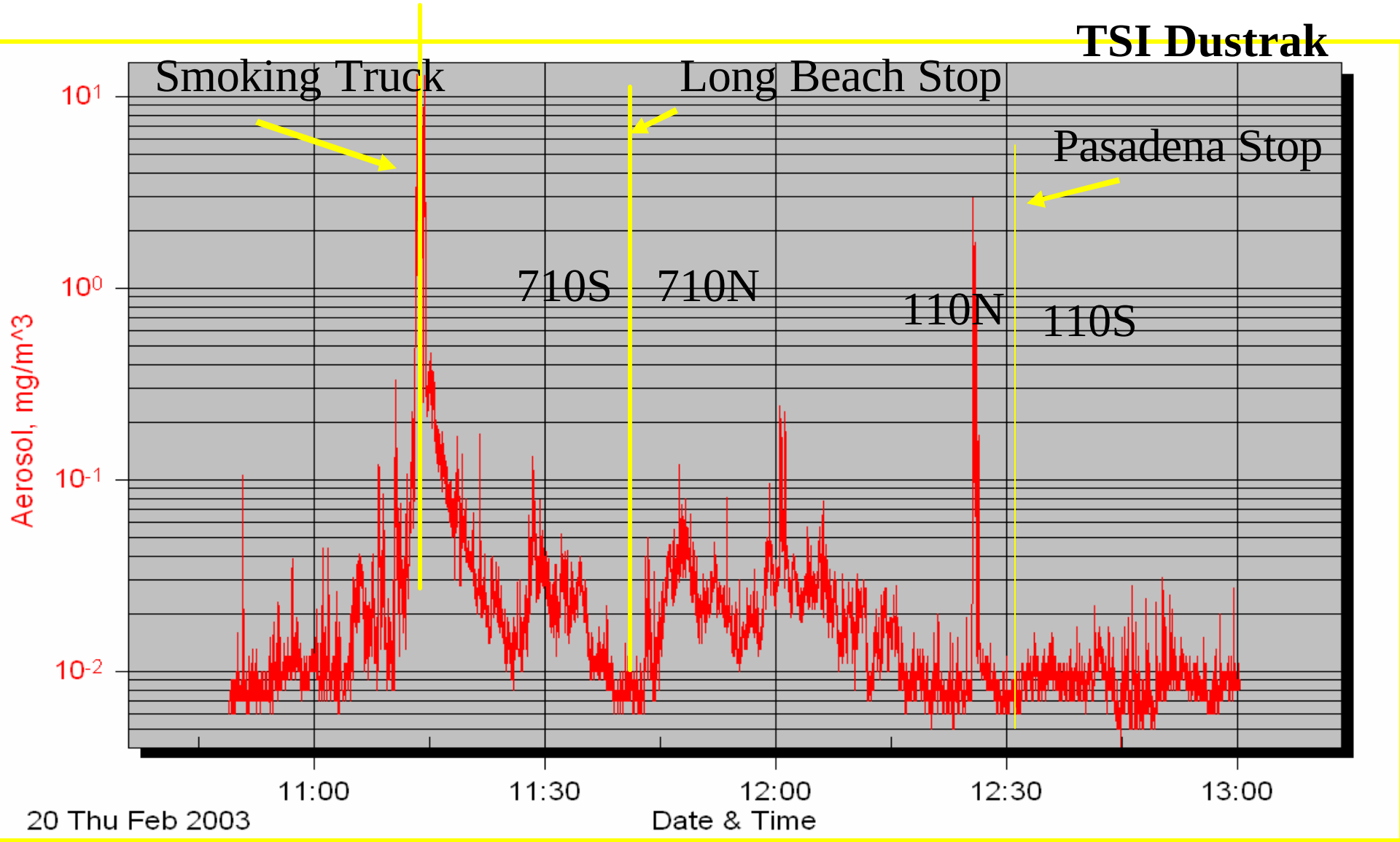
  **For newer, tighter vehicles, UFP reductions possible if ventilation re-circulated, but CO2 build-up a concern (i.e., > 2000 ppm)**

# Purpose

- **Characterize good predictors of in-vehicle concentrations of UFP and other vehicle-related pollutants**
  - **Better exposure assessment**
  - **Reduce exposure misclassification in epidemiology**

# High emitter of BC, $PM_{2.5}$

# In-Vehicle PM2.5



# High Diesel UFP Emitters

## Diesel school bus and TDI Jetta

## No visible emissions, similar effect

# Highest Gasoline-Powered UFP Emitter

## No visible emissions

# Effects of High Emitters, Exhaust Height

- **Average black carbon (BC) conc. behind different vehicle types, LA:**

| Vehicle Type | BC Concentration |
|---|---|
| No target or passenger car | 4.8 µg/m³ |
| Tractor trailer | 11 |
| Diesel passenger car | 18 |
| Delivery truck, high exh. | 14 |
| Delivery truck, low ex. | 23 |
| MTA bus, high exhaust | 18 |
| MTA bus, low exhaust | 64 |
| Highest emitter observed | >700 |

Fruin et al., 2004

# The Electric RAV4

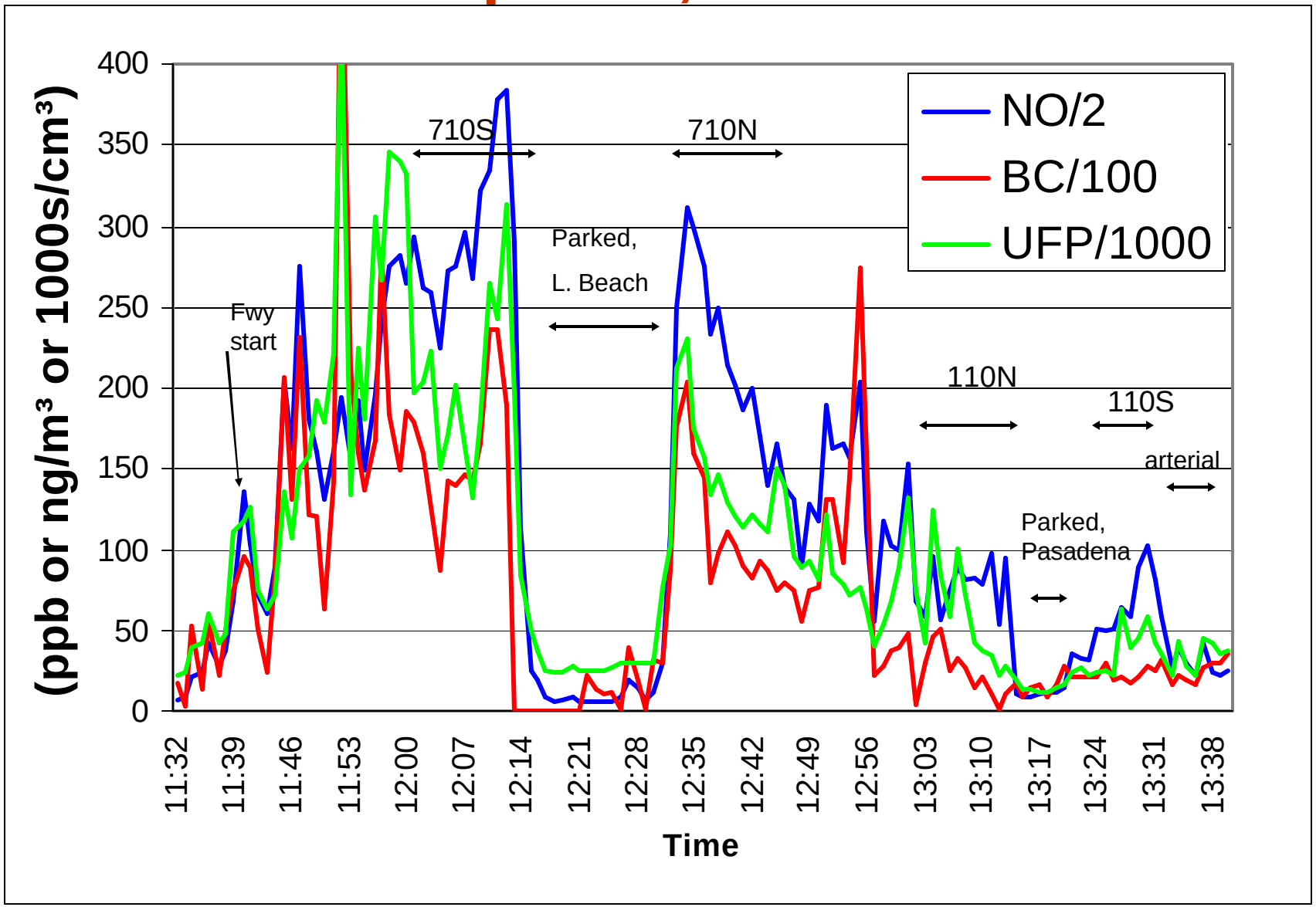
# 2003 Field Study Route


Real time:

BC, UFP, NO, $NO_2$, CO, $CO_2$, $PM_{2.5}$, PM size dist., PM-bound PAH

# Time Series: High Correlation

## April 16, 2003



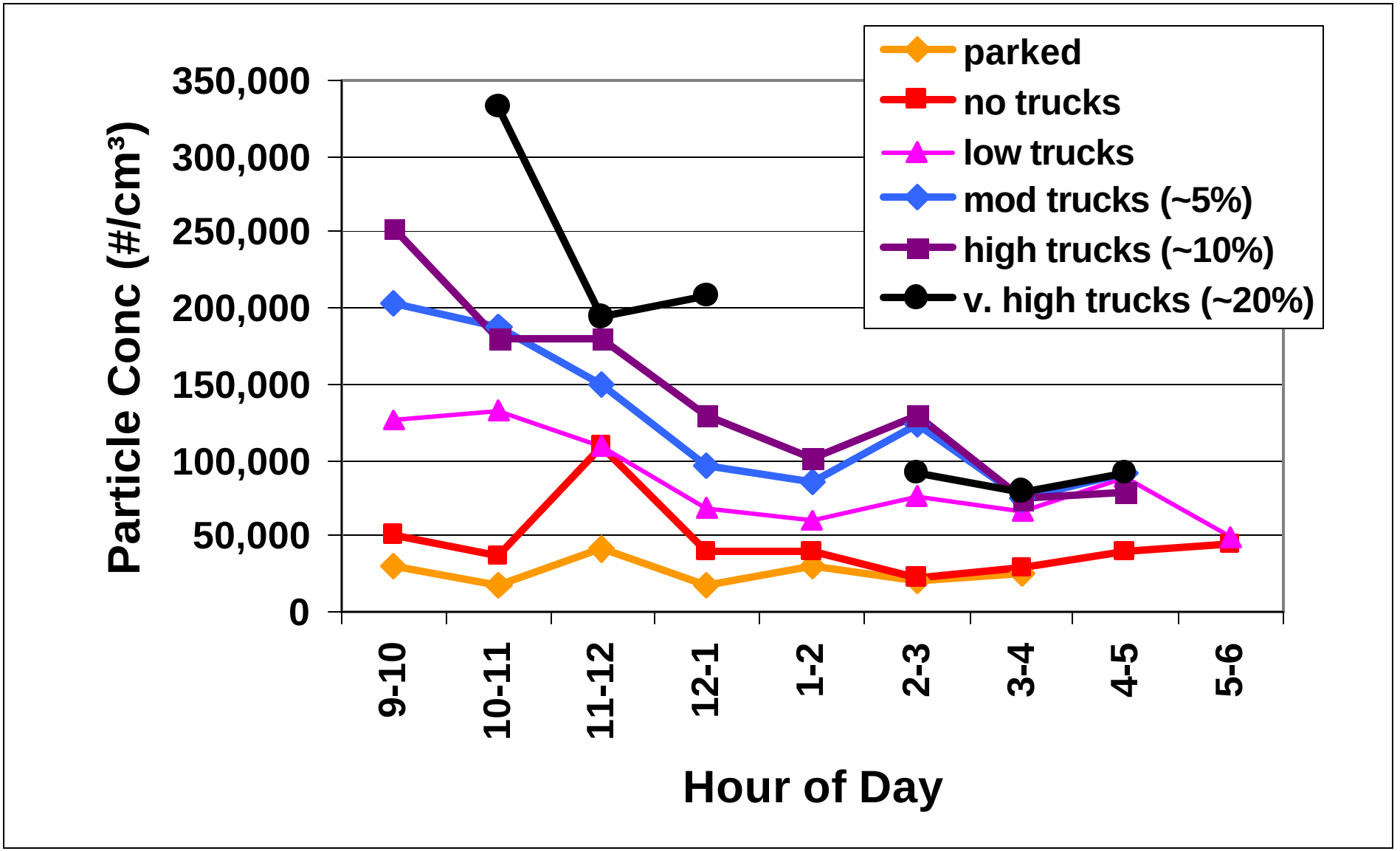
# Average In-Vehicle Concentrations for Four Days

| Location or roadway | Ultrafine particle counts (1000s $cm^{-3}$) | NO (ppb) | Black carbon ($\mu g\ m^{-3}$) | CO2 (ppm) | Avg. min. per run |
|---|---|---|---|---|---|
| Residential (Long Beach) | 27 ± 3 | 19 ± 7 | 1.4 ± 0.6 | 420 ± 70 | 14 |
| Arterial roads (N of USC) | 38 ± 20 | 90 ± 50 | 2.8 ± 1 | 730 ± 100 | 8 |
| 110N freeway near Pasadena (~300 trucks/day) | 43 ± 20 | 150 ± 40 | 1.6 ± 0.8 | 770 ± 50 | 15 |
| 110N freeway (~3000 trucks/day) | 67 ± 30 | 230 ± 60 | 3.9 ± 2 | 850 ± 30 | 10 |
| 10E freeway (~10,000 trucks/day) | 120 ± 50 | 260 ± 80 | 13 ± 5 | 1000 ± 40 | 5 |
| 710S freeway (~25,000 trucks/day) | 200 ± 80 | 400 ± 100 | 14 ± 5 | 850 ± 80 | 21 |

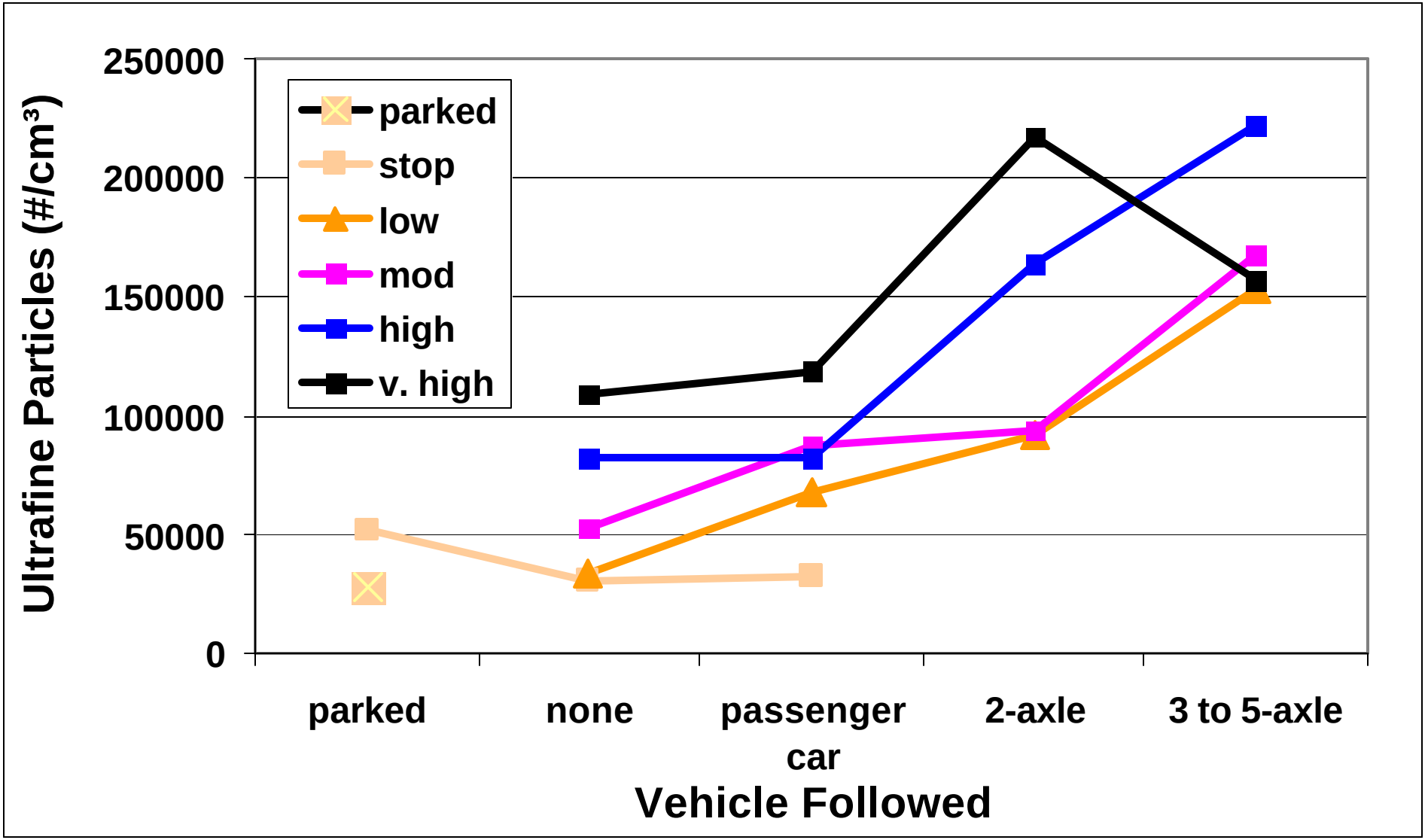
# Coeffs of Determination ($R^2$) for Predictor Variables of In-Vehicle Fwy UFP Concs

| PREDICTOR (# labels) | UFP (#/cm³) | NO (ppb) | Black Carbon (µg/m³) | CO (ppm) |
|---|---|---|---|---|
| **Road + Direction (17)** | 0.66 | 0.56 | 0.69 | 0.31 |
| **Truck Density (5)** | **0.58** | **0.57** | **0.64** | 0.096 |
| **Hr of Day (wind speed)(9)** | **0.26** | **0.24** | **0.26** | 0.11 |
| Vehicle Followed (6) | 0.20 | 0.18 | 0.18 | **0.24** |
| Speed (6) | 0.19 | 0.23 | 0.18 | 0.11 |
| Overall Congestion (5) | 0.14 | 0.15 | 0.14 | **0.23** |
| Day (4) | 0.095 | 0.19 | 0.09 | 0.15 |
| **Best two variables (green)** | **0.68** | **0.65** | **0.69** | **0.28** |

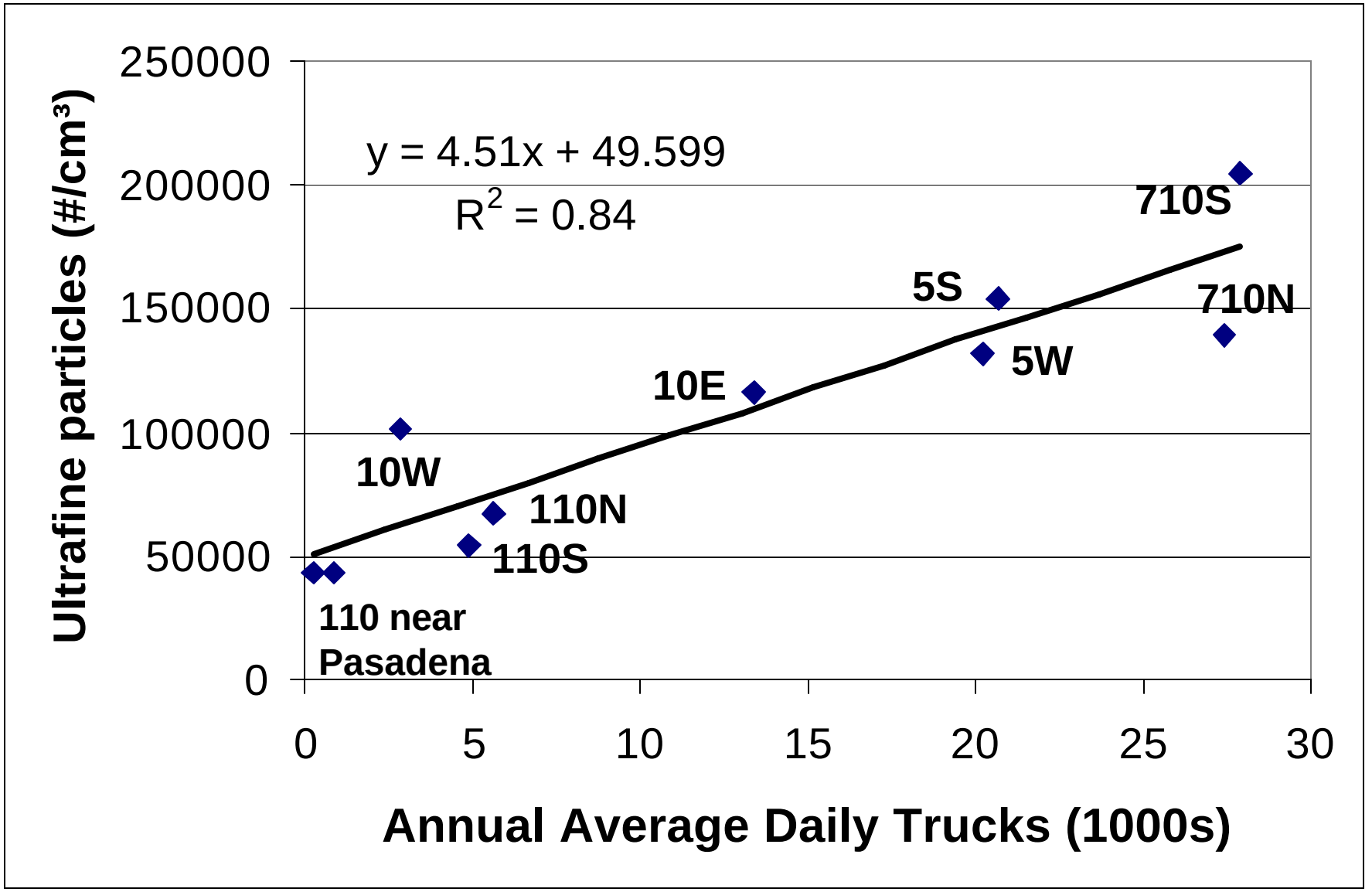
# Effect of Truck Density by Hour of Day



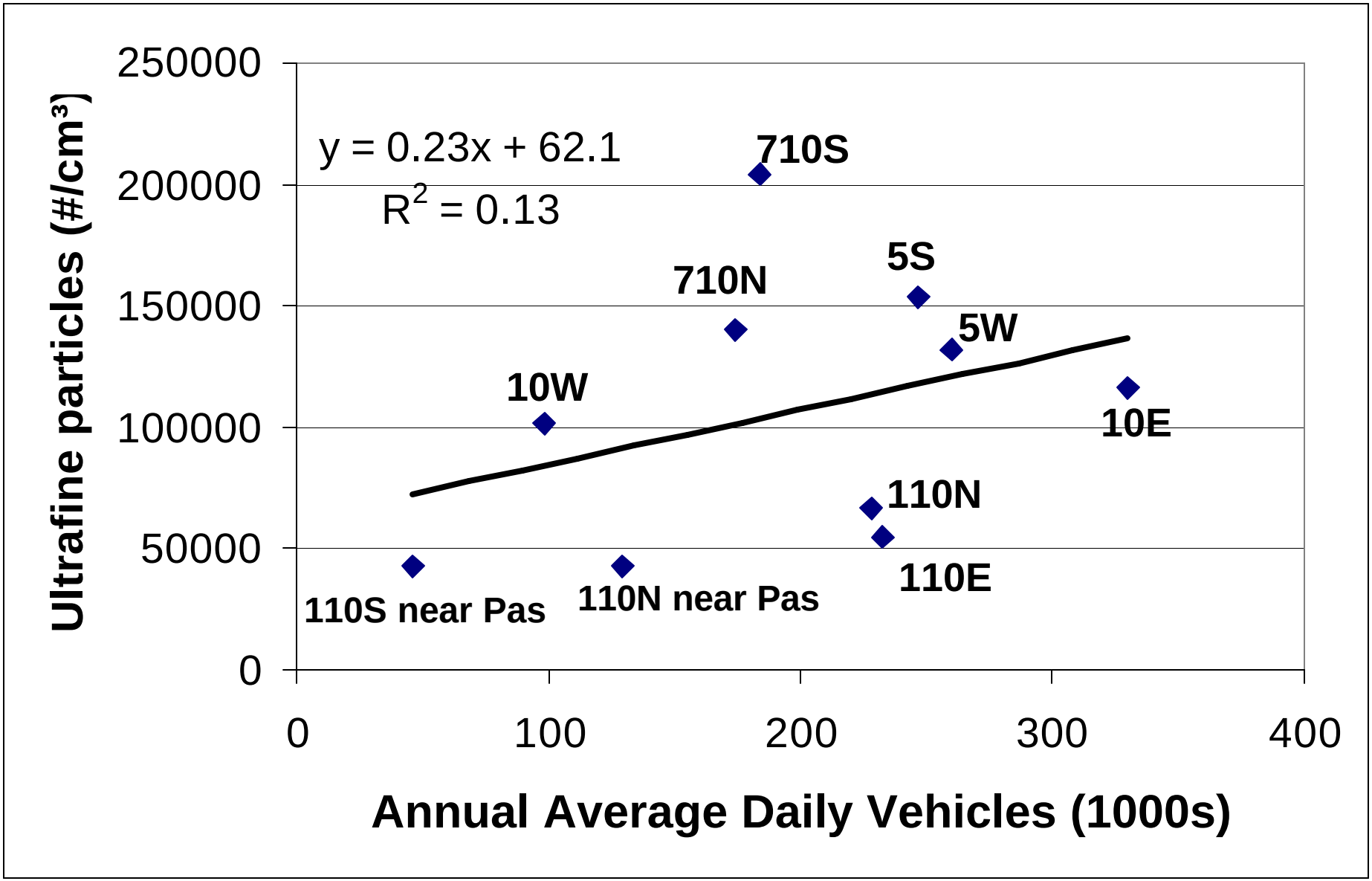
# Effect of Speed and Vehicle Followed



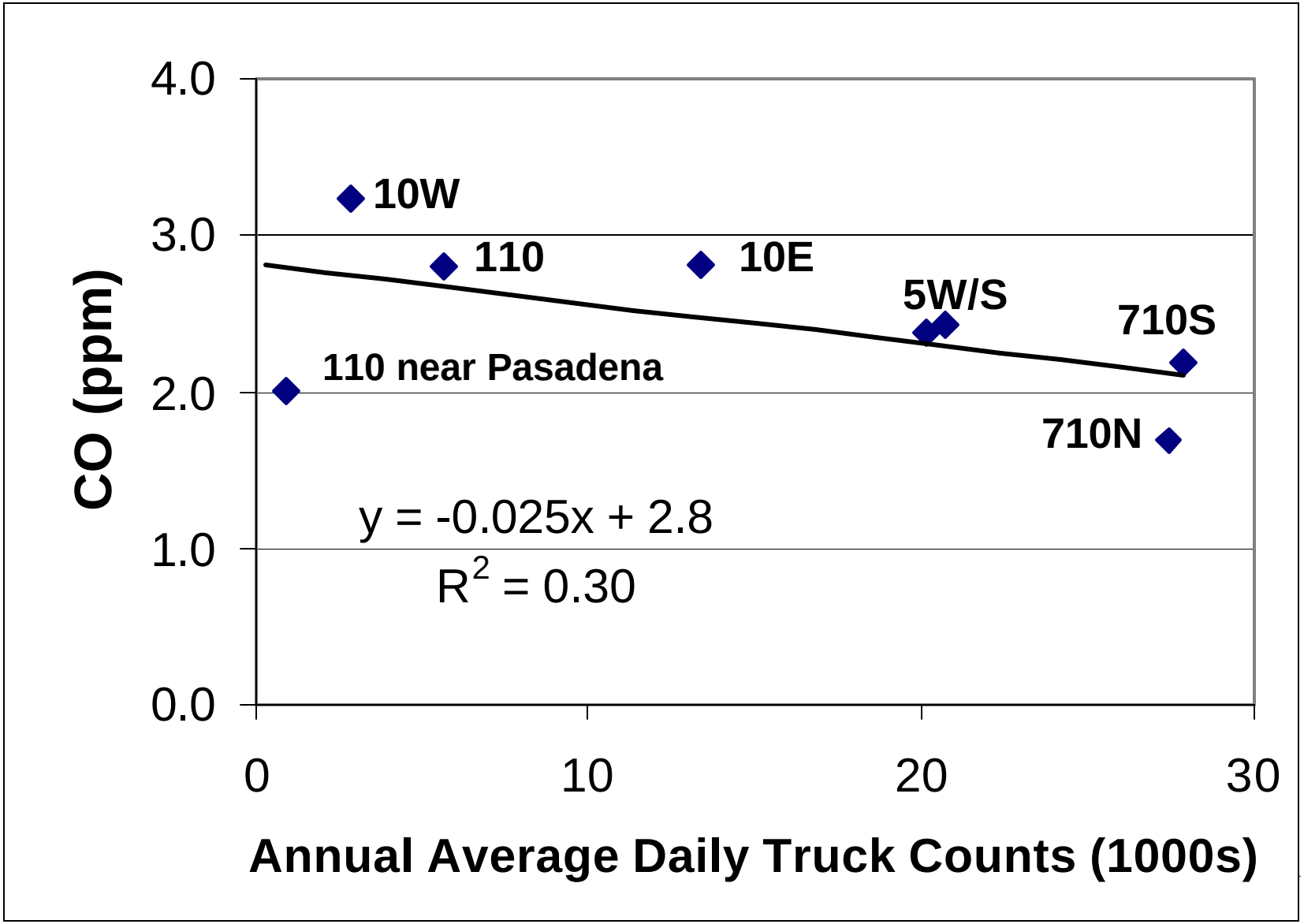
# Relationship between UFP and Average Daily Truck Count (2003)



# Relationship between UFP and Average Vehicle Count (2003)

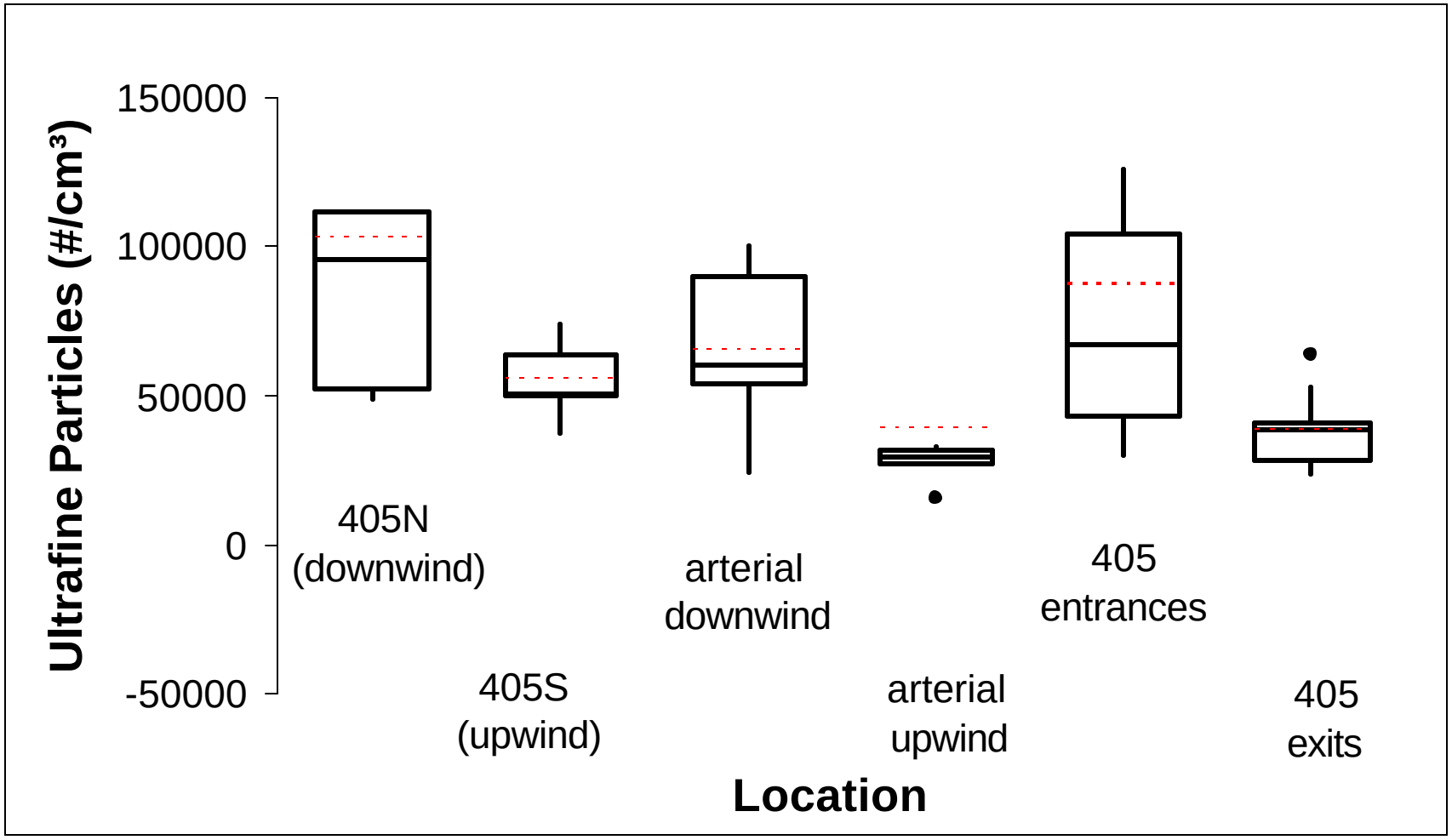


# Relationship between CO and Average Daily Truck Count (2003)

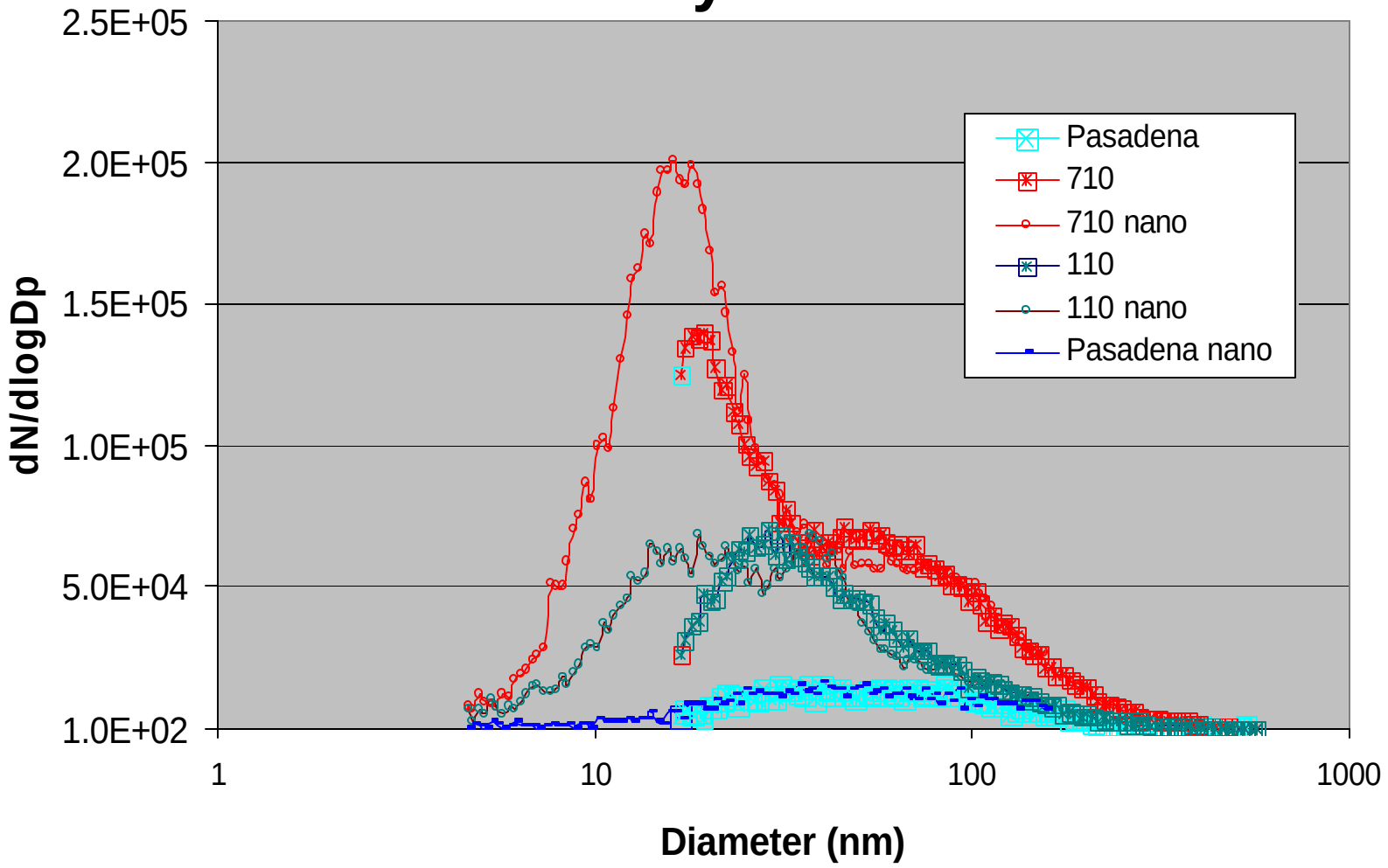


# Effect of Lane Position

## 405 Freeway, Los Angeles



# Particle Size Distribution
# 710 + 110 Freeways and Pasadena

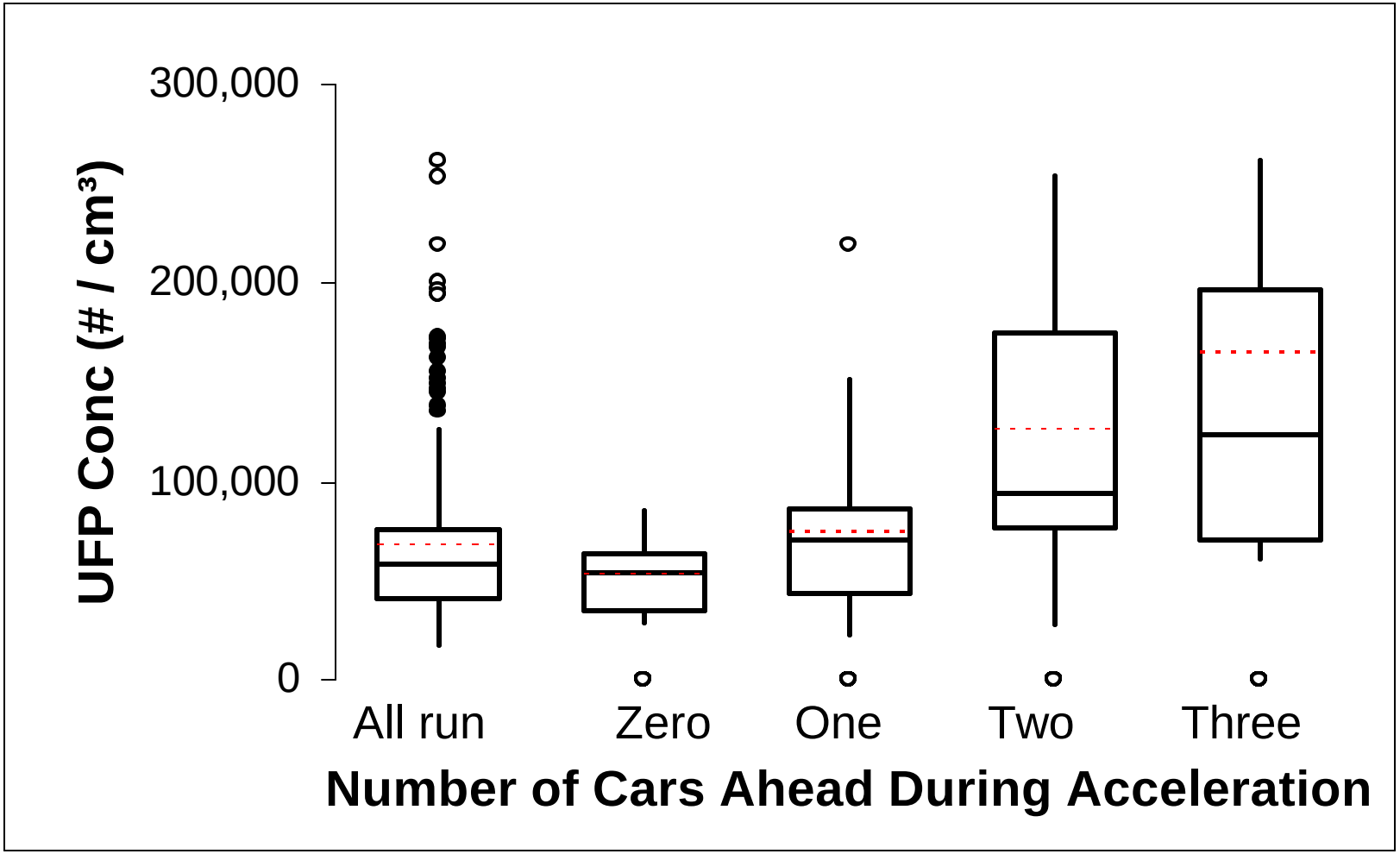


# Arterial Roads and UFP Concentrations

- Arterial mileage approx. equal to fwy, speed approx. half
- UFP concentrations 1/3 to 1/2 of freeways
  - ↓ Fewer trucks, fewer lanes, lower speeds(?)
  - ↑ Harder accelerations, closer distances
- Stop lights and accelerations key
- Good predictors of UFP concentrations more difficult
  - Surrounding vehicle orientation, wind speed critical, yet difficult to characterize

# Arterial Route

## Western, 120th, Avalon, Jefferson



# Estimate of In-Vehicle Fraction of Total UFP Exposure

- **Typical UFP Conc. and Times:**
  - **Residential 8 hrs 2000/cm³ (night)**
  - **Residential 5 hrs 5000/cm³ (evening)**

**(both from Wallace et al., 2004)**

  - **Workplace (office) 5.5 hrs 5000/cm³**
  - **Outdoors 1 hr 20,000/cm³**
  - **In-vehicle arterial 1.0 hr 50,000/cm³**
  - **In-vehicle freeway 0.5 hr 150,000/cm³**
  - **Wt'd avg. conc. of ~10,000/cm³**

**(matches Abraham et al., 2002)**

- **>50% exposure from in-vehicle time**

**(Ignores high workplace exposures, smoking or ETS exposure)**

# Conclusions

- **In-vehicle time contributes significantly to overall UFP exposures; both freeway and arterial time important**

  **Probably > 50% of total exposure on average for non-smoking urbanites**

- **In-vehicle UFP concentration can be well-predicted on freeways from:**
  - **Surrounding truck counts (real time) -or-**
  - **Average truck counts for a given roadway segment**
- **On arterial roads:**

  **Number of surrounding gasoline-powered vehicles making hard accelerations from stoplights**

# Thanks

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- **Others**

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